

UPLINK SINR ESTIMATION

TECHNICAL FIELD

5 The present invention relates to estimation of the Signal to Interference plus Noise Ratio (SINR) of Code Division Multiple Access (CDMA) channels.

BACKGROUND

10 The SINR is an important link performance indicator used in CDMA systems for various radio network algorithms, such as inner-loop power control. The SINR estimation is very critical, since it indirectly affects the power management at both base station and mobile station. It is required that the estimated SINR actually reflects the experienced radio link quality and, moreo-
15 ver, that the estimation is as accurate as possible.

The SINR estimate is formed by measuring the signal power "S", and the interference plus noise power, "IN". Although it is quite straightforward to measure "S", it is far from obvious how to measure "IN".

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A previously known method of estimating the power of interference plus noise (IN) is to re-generate the pilot symbols (after de-spreading) and calculate their average deviation from the ideal signal points. However, since the SINR is measured every time slot, there are only a few (2-8) pilot symbols
25 available, which means that the obtainable accuracy of the IN measurement is very limited. Since the same IN estimate is used for SINR estimation of any channel, it is appreciated that these estimates will also have limited accuracy.

30 Another method described in [1, 2] is to reserve one downlink channelization code as an "interference plus noise measurement code" which is never used

for information transfer. This method generates a downlink IN estimate by de-spreading the received signal with the reserved code. However, this method has several drawbacks. Firstly, it requires a redefinition of existing standards, since it reserves codes for IN measurements. Secondly, in order to avoid a shortage of channelization codes, a code having a high spreading factor (SF=256) is reserved. This limits the obtainable accuracy improvement, since a higher spreading factor corresponds to fewer symbols.

SUMMARY

An object of the present invention is to improve the accuracy of the uplink SINR estimation, and especially of the interference plus noise estimation, without requiring any changes to existing standards.

This object is achieved in accordance with the attached claims.

Briefly, the present invention selects an idle (not used) channelization code, which preferably has the lowest possible spreading factor, and uses this code to estimate the power of interference plus noise. An advantage is that since an idle code is selected, there is no need to change existing standards. Another advantage of using an idle code (such codes are always available on the uplink) is that there will be no code shortage due to SINR measurements. Furthermore, the method makes it possible to search the code tree down to lowest possible spreading factor, thereby increasing the number of symbols in the IN measurement, which will result in a very high accuracy of the IN estimate.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention, together with further objects and advantages thereof, may best be understood by making reference to the following description taken together with the accompanying drawings, in which:

Fig. 1 is a conceptual block diagram of a prior art SINR estimation arrangement;

Fig. 2 is a diagram illustrating the structure of an OVSF code tree;

Fig. 3 is an OVSF code tree diagram illustrating idle codes when a single
5 DPDCH is used;

Fig. 4 is an OVSF code tree diagram illustrating idle codes when 2
DPDCHs are used;

Fig. 5 is an OVSF code tree diagram illustrating idle codes when 3-4
DPDCHs are used;

10 Fig. 6 is an OVSF code tree diagram illustrating idle codes when 5-6
DPDCHs are used;

Fig. 7 is a conceptual block diagram of an exemplary embodiment of a
SINR estimation arrangement in accordance with the present invention;

15 Fig. 8 is a conceptual block diagram of another exemplary embodiment of
a SINR estimation arrangement in accordance with the present invention;

Fig. 9 is a diagram illustrating the performance improvement that can be
obtained by the present invention; and

Fig. 10 is a flowchart illustrating an exemplary embodiment of the meth-
od in accordance with the present invention.

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DETAILED DESCRIPTION

In the following description the same reference designations will be used for the
same or similar elements throughout the figures of the drawings.

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Furthermore, it is assumed that only BPSK or QPSK modulation is employed,
that Orthogonal Variable Spreading Factor (OVSF) codes are used as chan-
nelization codes and that the scrambling code is a complex sequence with a
Long enough period. Both WCDMA and CDMA2000 fulfill these assumptions.

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The SINR for the de-spread symbols and de-modulated raw bits is generally defined respectively as:

$$SINR_{sym} = \frac{S_{sym}}{IN_{sym}} = \frac{\|E(symbol)\|^2}{Var(symbol)}$$

$$SINR_{bit} = \frac{S_{bit}}{IN_{bit}} = \frac{[E(bit)]^2}{Var(bit)}$$

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where "E()" denotes expectation (statistical averaging). If the phase compensation is perfect, then:

$$SINR_{bit} = \begin{cases} 2 \cdot SINR_{sym}, & \text{for BPSK} \\ SINR_{sym}, & \text{for QPSK} \end{cases}$$

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For this reason, this document will primarily discuss SINR for the de-modulated raw bits, and the term "SINR" will generally stand for "SINR_{bit}".

Different vendors may have different ways to estimate SINR. As an example
 15 Fig. 1 illustrates a generic CDMA receiver with function blocks to estimate the SINR by utilizing the associated pilot. The associated pilot is a pre-known symbol/bit that is transmitted at the same time (in the sense that both the multi-path channel and the interference plus noise power are almost non-varying) and from the same transmitter as the data. Both the dedicated pilot
 20 and common pilot in WCDMA and CDMA2000 are examples of such an associated pilot.

Fig. 1 is a conceptual block diagram of a prior art SINR estimation arrangement. The received signal samples are forwarded to a receiver filter 10. Receiver filter 10 is either a multi-path channel matched filter or an equalizer. The filtered signal is de-scrambled by the complex conjugate SC^* of the complex scrambling code. The de-scrambled signal is de-spread into two parallel signal streams $ru_{data}(n)$ and $ru_{pilot}(n)$ by multiplication with the respective channelization codes CC_{data} and CC_{pilot} and integration in integrators 12 and 14, respectively. The pilot signal branch is used for the SINR estimation by first multiplying $ru_{pilot}(n)$ with the complex conjugate of the corresponding known signal $u_{pilot}(n)$ for obtaining the product signal $ruu_{pilot}(n)$ on which the SINR measurement is based. SINR is then estimated in blocks 16, 18 and 20 using the following equations:

$$\hat{SINR}_{pilot} = \begin{cases} 2 \cdot \left(\frac{\|m_{pilot}\|^2}{(std_{pilot})^2} - \frac{1}{N_{pilots}} \right), & \text{for BPSK} \\ \frac{\|m_{pilot}\|^2}{(std_{pilot})^2} - \frac{1}{N_{pilots}}, & \text{for QPSK} \end{cases} \quad \text{Calculated in block 20}$$

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where

$$m_{pilot} = \frac{1}{N_{pilots}} \cdot \sum_{n=1}^{N_{pilots}} ruu_{pilot}(n) \quad \text{Calculated in block 16}$$

$$std_{pilot} = \sqrt{\frac{1}{N_{pilots} - 1} \cdot \sum_{n=1}^{N_{pilots}} \|ruu_{pilot}(n) - m_{pilot}\|^2} \quad \text{Calculated in block 18}$$

20 and N_{pilots} is the number of pilot symbols used in the estimation (1 symbol = 1 bit for BPSK and 2 bits for QPSK). This SINR estimation for the associated pilot follows the general SINR definition above, but removes the bias in the signal power estimation.

In general the SINR of a data channel can be estimated by simply scaling the estimated SINR of the associated pilot:

$$\hat{SINR}_{data} = \frac{MF_{data}}{MF_{pilot}} \cdot \frac{SF_{data}}{SF_{pilot}} \cdot \frac{P_{data}}{P_{pilot}} \cdot \hat{SINR}_{pilot}$$

where

MF_{data} = modulation factor for the data (2=BPSK, 1=QPSK)

MF_{pilot} = modulation factor for the associated pilot (2=BPSK, 1= QPSK)

SF_{data} = the spreading factor for the data

10 SF_{pilot} = the spreading factor for the associated pilot

P_{data} = the transmission power for the data

P_{pilot} = the transmission power for the associated pilot.

15 In WCDMA and CDMA2000 the downlink employs QPSK modulation and the uplink employs BPSK modulation.

The described method is typical for the uplink dedicated physical data channel utilizing the uplink dedicated pilot in WCDMA and CDMA2000 for SINR estimation. If this estimation method is used, then:

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$$\frac{\hat{SINR}_{data}}{SINR_{data}} = \frac{\hat{SINR}_{pilot}}{SINR_{pilot}}$$

i.e. the estimated data SINR has the same accuracy as the estimated pilot SINR. The estimation accuracy is defined as:

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$$accuracy = Probability \left(-X_{dB} < 10 \cdot \log_{10} \left(\frac{SINR_{estimated}}{SINR_{actual}} \right) < X_{dB} \right)$$

It is required by the "3rd Generation Partnership Project" (3GPP) that the accuracy $\geq 90\%$ for $X_{dB} = 3$ dB in the interval -7 dB $< 10 \cdot \log_{10}(SINR_{actual}) < 7$ dB with 80 ms averaging interval.

In WCDMA an estimated SINR should be generated every time slot (0.667 ms) and input to the inner-loop power control algorithm. If we assume that the multi-path channel and the interference plus noise power is almost non-varying during one time slot, then the demodulated raw bits are Gaussian distributed and the SINR is fixed during the whole time slot. The dedicated physical control channel has only 2-8 dedicated pilot symbols (1 symbol=2 bits) per time slot in the downlink and 3-8 dedicated pilot symbols (1 symbol=1 bit) in the uplink depending on slot format. The estimation accuracy relies on the number of associated pilots that are used in the estimation, the more pilots the higher estimation accuracy.

One solution to improve the estimation accuracy is to measure the effective interference plus noise power on a different measurement object than the measurement of the signal power, so that more symbols can be utilized. In accordance with the present invention, on the uplink the measurement of the effective interference plus noise power is performed on an idle code channel. An idle code is an OVSF code that is not occupied as a channelization code, or used to generate channelization code(s). Fig. 2 illustrates an OVSF code tree. The channelization codes are uniquely described as $C_{ch,SF,k}$, where SF is the spreading factor of the code and k is the code number, $0 \leq k \leq SF-1$. Each level in the code tree defines channelization codes of length SF, corresponding to a spreading factor of SF. The leftmost value in each channelization code word corresponds to the chip transmitted first in time. An

important feature of the OVSF code tree is that channelization codes from different branches are orthogonal to each other regardless of spreading factor SF. This feature is used by the present invention, as will be described below.

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In order to get an accurate estimate of the effective interference plus noise power, the spreading factor (SF) of the idle code should preferably be as low as possible, so that as many symbols as possible can be used during the same time slot. The lowest SF for an idle code is 2 if all the used codes are
10 from the same half of the OVSF tree. More specifically, if all channelization codes are derived from the OVSF code (1, 1), then OVSF code (1, -1) can be used as the idle code, or vice versa.

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This proposed idle code scheme neither requires any changes to existing standards nor creates any extra signalling burden. Since the base station already knows a user's channelization codes in order to de-spread the different code channels from this user, it can derive the best idle code by looking up the OVSF code tree. More specifically, from the 3GPP specification [3] the following conclusions can be derived for WCDMA:

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1. The channelization code $C_{ch,2,1}$ (SF=2) is always idle when 1 or 2 DPDCHs are transmitted on the uplink, as illustrated in Fig. 3 and 4 (in fact the entire lower branch includes idle codes, but $C_{ch,2,1}$ has the lowest spreading factor (SF=2) and is thus preferred).

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2. The channelization code $C_{ch,4,2}$ (SF=4) (and the branch starting there) is always idle when 3 or 4 DPDCHs are transmitted on the uplink, as illustrated in Fig. 5.

3. The channelization code $C_{ch,8,1}$ (SF=8) (and the branch starting there) is always idle when 5 or 6 DPDCHs are transmitted on the uplink, as illustrated in Fig. 6.

- 5 The idle code channel may be viewed as a channel with zero transmission power, and by using the same analysis method as in [4] it can be shown that:

$$Var(ru_{desired}) = \frac{SF_{idle}}{SF_{desired}} \cdot Var(ru_{idle}) = \frac{SF_{idle}}{SF_{desired}} \cdot E(\|ru_{idle}\|^2)$$

- 10 Thus, by proper rescaling, the variance estimation of a desired channel may be performed on an idle channel instead.

If the desired code channel has time-multiplexed pilot symbols, which is the case for the Dedicated Physical Control Channel (DPCCH), for example, then
 15 the estimated SINR for the desired code channel can be calculated as illustrated by the arrangement in Fig. 7, which illustrates the parts of a base station that are essential for explaining this exemplary embodiment of present invention. In this embodiment the de-scrambled signal is de-spread into two parallel signal streams $ru_{DPCCH}(n)$ and $ru_{idle}(n)$ by multiplication with
 20 the respective channelization codes CC_{DPCCH} and CC_{idle} and integration in integrators 12 and 14, respectively. The idle channelization code has been selected by an idle code selection block 28 based on the OVSF code tree in Fig. 2 and occupied codes known to the base station. It may, for example, be implemented as a simple lookup table. SINR is then estimated in blocks 16,
 25 30 and 32 using the following equations:

$$\hat{SINR}_{DPCCH} = 2 \cdot \left(\frac{\frac{\|m_{pilot}\|^2}{SF_{idle}}}{\frac{m_{idle}^2}{SF_{DPCCH}}} - \frac{1}{N_{pilots}} \right) \quad \text{Calculated in block 32}$$

where

$$m_{pilot} = \frac{1}{N_{pilots}} \cdot \sum_{n=1}^{N_{pilots}} ruu_{pilot}(n) \quad \text{Calculated in block 16}$$

$$m_{\|idle\|^2} = \frac{1}{N_{idle}} \cdot \sum_{n=1}^{N_{idle}} \|ru_{idle}(n)\|^2 \quad \text{Calculated in block 30}$$

and

- 5 N_{pilots} is the number of pilot symbols used in the estimation
 N_{idle} is the number of idle symbols used in the estimation.

Here the notation $m_{\|idle\|^2}$ is used to indicate that the average is formed from the squared norm of the signal samples.

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- If the desired code channel does not have any pilot symbols, which is the case for the Dedicated Physical Data Channel (DPDCH), for example, then the estimated SINR for the desired code channel can still be non-coherently calculated as illustrated by the arrangement in Fig. 8, which illustrates the parts of a base station that are essential for explaining this exemplary embodiment of present invention. In this embodiment the de-scrambled signal is de-spread into two parallel signal streams $ru_{DPDCH}(n)$ and $ru_{idle}(n)$ by multiplication with the respective channelization codes CC_{DPDCH} and CC_{idle} and integration in integrators 12 and 14, respectively. The idle channelization code has been selected by an idle code selection block 28 based on the OVSF code tree in Fig. 2 and occupied codes known to the base station. It may, for example, be implemented as a simple lookup table. SINR is then estimated in blocks 30, 40 and 42 using the following equations:
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$$\hat{SINR}_{DPDCH} = 2 \cdot \left(\frac{m_{\|DPDCH\|^2}}{\frac{SF_{idle}}{SF_{DPDCH}} \cdot m_{\|idle\|^2}} - 1 \right) \quad \text{Calculated in block 42}$$

where

$$m_{\|DPDCH\|^2} = \frac{1}{N_{DPDCH}} \cdot \sum_{n=1}^{N_{DPDCH}} \|ru_{DPDCH}(n)\|^2 \quad \text{Calculated in block 40}$$

$$m_{\|idle\|^2} = \frac{1}{N_{idle}} \cdot \sum_{n=1}^{N_{idle}} \|ru_{idle}(n)\|^2 \quad \text{Calculated in block 30}$$

and

N_{DPDCH} is the number of signal symbols used in the estimation

N_{idle} is the number of idle symbols used in the estimation.

The functionality of the arrangement of the present invention is typically implemented as a microprocessor or a micro/signal processor combination and corresponding software.

For WCDMA uplink the described prior art method only utilizes the 3~8 dedicated pilot symbols to estimate the SINR. In contrast the method in accordance with the present invention may maximally utilize 1280 (2560/2) "idle symbols" to measure the effective interference plus noise power during one time slot. This is a main benefit of using an idle code channel (with low spreading factor) to assist the SINR estimation. The new method can also utilize all of the 10 DPCH symbols to measure the DPCH power, and all symbols on the DPDCH channel to measure the DPDCH power. Fig. 9 is a diagram illustrating the performance improvement that can be obtained by the present invention. The figure compares the SINR estimation based on an idle code channel (SF=2) with the SINR estimation based on 8 dedicated pilot

symbols (1 symbol = 1 bit due to BPSK modulation). The estimation accuracy is improved from 70% to 95% ($X_{dB} = 3 \text{ dB}$) in this example. If the dedicated pilot symbols are fewer than 8, then the improvement is even larger.

5 Fig. 10 is a flowchart summarizing an exemplary embodiment of the method in accordance with the present invention. Step S1 estimates the power of a desired channel using its channelization code. Step S2 searches for and selects a low SF idle channelization code from the OVSF tree using information regarding occupied channelization codes. Step S3 estimates the power of interference plus
10 noise using the determined idle channelization code. Step S4 forms an estimate of SINR using the determined power estimates. If the channelization codes have different spreading factors, the estimates obtained in step S3 is rescaled accordingly. Finally, step S5 returns the procedure to step S1 for estimating SINR of the next time slot.

15 It will be understood by those skilled in the art that various modifications and changes may be made to the present invention without departure from the scope thereof, which is defined by the appended claims.

REFERENCES

- [1] TSGR1#4(99)348, "Proposal for downlink interference measurement method". TSG-RAN Working Group 1 meeting #4, Shin-Yokohama, Japan, April 18-20, 1999.
- [2] WO 00/57654.
- [3] TS 25.213, "Spreading and modulation (FDD)," version 3.1.0.
- [4] Wang Hai, Niclas Wiberg, "Analysis of a CDMA downlink in multi-path fading channels," in Proceeding IEEE Wireless Communication & Networking Conference (WCNC), Orlando, FL, Mar. 17-21, 2002, pp. 517-521.